Status of the ECR Ion Source at the INS SF Cyclotron

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Abstract

The ECR ion source installed at the SF cyclotron (named SF-ECR) is in routine operation with the cyclotron. The ions accelerated and supplied for nuclear experiments cover the mass range from carbon to neon and the energy range of 4 to 9.5 MeV/u. Transmissions from the source to the cyclotron exit are 2-5 %.

Recently, a beam of 6 Li 2+ from solid material has been used successfully for an experimental run. Intensities of the analyzed and extracted beam of 6 Li 2+ are tpically 16 μA and 0.6 μA, respectively.

Introduction

At the INS SF-cyclotron facility, the ECR source, the beam injection line and the cyclotron center region have worked well since coming into routine operation in August 1989.

The ECR-source has been delivering mainly a gaseous ion beams to the cyclotron. The operation has been successful in terms of reliability, stability, production of high chage state ions. A detailed discussion of the operating characteristics of the SF-ECR has been published elsewhere [1].

We have built an oven system heated by a filament. This oven system has been used for injection of low melting point elements into the ECR plasma. Due to the sample vaporizing at low temperature, the vapor from the oven is controlled by varying the filament power.

Performance tests of lithium ion beams have been carried out so that charged lithium metal with this oven is used for longer experimental run. The present consumption rate of lithium metal injected into the ECR plasma obtained is about 17 mg/h.

We know from some operating tests that the insde of the plasma chamber is covered with lithium metal, and that the beam intensities of gaseous elements become a half after lithum experimental run. These problem have been improved by cleaning the insede of the chamber and baking with rf power for almost one week.

So that larger beam from the ECR source can reach at the cyclotron exit, performance test, tuning and improvement of the beam injection line have been carried out by using mainly oxygen. Some of the results of these efforts are described below. [2],[3]

A gridded buncher of a two-gap type is placed 3.5 m above the cyclotron midplane. A wide-band rf amplifier together with an all-pass network produces about 200 V at the electrode for the entire range of cyclotron frequencies. The gain of the beam intensity when the buncher works is around twice to three times.

In order to shield the first half turn beam against the rf field, a gridded electrostatic mirror with a wing has been set at the cyclotron center region. The intensity at radius 150 mm of the cyclotron has increased up to 13 % of the analyzed beam in the fundamental mode.

More than 80 % of the analyzed beam with emittance 200 π mm.mrad can reach a Faraday cup just above the magnetic yoke. However, the transmission through the electric quadrupole triplet and the hole lens of the cyclotron main magnet is 20 % to 50 % of the analyzed beam.

After the ECR ion source was installed at the SF cyclotron, in routine work, about 30 % of the cyclotron operating schedule has been with the ECR source. The light-ion filament source is used for runs of proton, 3 He and alpha beams.

In this paper we describe the present status of the SF-ECR ion source and the production of metallic ions by using this source.

SF-ECR Ion Source

The configuration of the SF-ECR is shown in Fig. 1, together with the measured magnetic field distribution on axis. This was used for 6 Li 2+ production.

The SF-ECR has a closed ECR zone at the second stage and an open ECR zone at the first stage. The solenoid coils is separated into three groups. Two groups coils are used to produce the axial magnetic field. A set of SmCo5 sextupole magnets is installed in the second stage only to produce the radial magnetic field. A piece of iron is placed near the exit of the first stage to increase the magnetic field more than twice of the ECR field. Electric power consumption is typically 30 kW.

The oven is inserted radially near the center of the ECR zone (about 150 mm in length), so that the vapor may reach the both ends of it.

The microwave power of 6.4 GHz is fed radially into the second stage only. The second stage is operated by a level of 100 to 300 W depending on ion species. The wave guide bent to the direction of the extractor is set against the oven nozzle. In this arrangement, the microwave window is protected against the metallic vapor to hit and cover on it. Since then, it has not occurred that micro-wave is cut off.

Gas is fed through a quartz tube (with a diameter of 1cm) which is inserted in the first stage. The source is pumped by two 1500-l/s turbomolecular pumps. Due to the structure being pumped out radially, density of neutral molecules in the plasma chamber is easily controlled. Because the chamber has large conductance. The pressure for optimum beam current is about 1.0 *10 -6 Torr at the second stage.

Metallic ion production

Two different methods heating the oven have been tried for evaporation of solid material : direct heating of the oven by the ECR plasma and heating by a hot filament. In the direct heating method, several microamperes of Li, Mg and Al ions are obtained, however, controlling the position of the oven and finding the optimum parameters to obtain maximum ion current are found to be delicate.

For routine operation, the filament heating method is used. Because it has a stable performance. The oven is inserted radially into the second stage so that vaporized metal streams into the ECR plasma and is ionized by electron bombardment.

The plasma is maintained by running helium as a support gas in the first stage. The amount of metal in the plasma is adjusted by varying the oven temperature with changing directly filament power.

For lithium, the measured consumption rate is found to be in good agreement with the mass flow rate calculated by using the conductance of the oven nozzle (4 mm in diameter) and the vapor pressure of lithium at the operating temperature. Typical operating condition for producing 16 μA of the 6 Li 2+ beam from the ECR has been obtained at an oven temperature of 520 $^\circ$C which corresponds to a lithium vapor pressure of 6 * 10 -3 Torr. The lithium consumption rate is 17 mg/h.

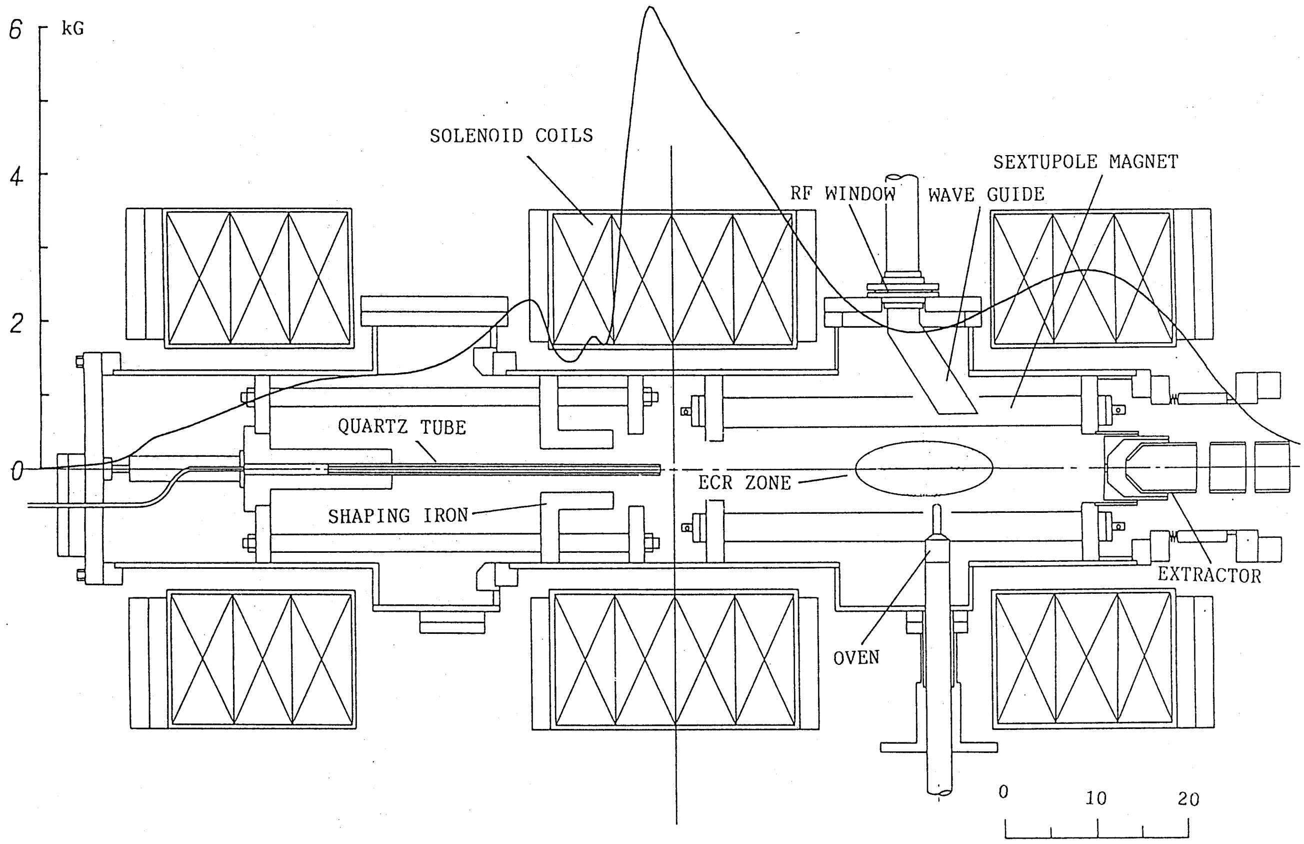

Fig. 1 The SF-ECR ion source with the oven installed and a typical magnetic field distribution during 6 Li 2+ beam operation.

In the case of 6 Li 2+ beam production, lithium (95% enriched) charged in the oven is 0.5 g, and the used time of material with this oven is about 29 hours. When the 6 Li 2+ beam from the ECR is 16μA, the beam extracted from the cyclotron is typically 0.6μA depending somewhat on energy and cyclotron tuning.

Performance and results

The performance of SF-ECR is summarized in Fig. 2 and 3. The ions are accelerated up to 10 kV. The slit width at the entrance and exit of the analyzing magnet are 20 mm and 10 mm, respectively. The beam currents represent the best results when the ECR source works at the optimum rf power and gas flow rate searched by many trials.

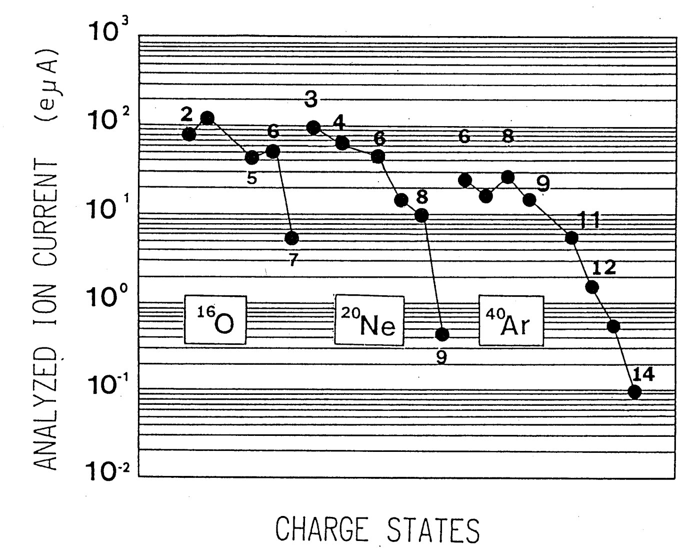

Fig. 2 Chage state distribution of O, Ne and Ar ions.

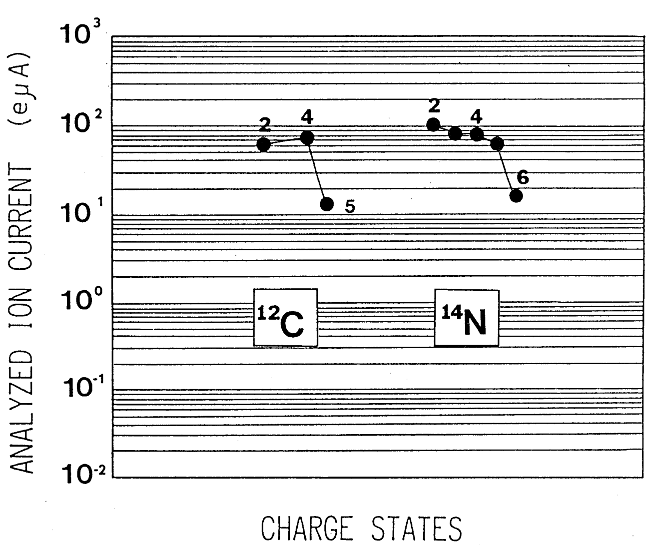

Fig. 3 Chage state distribution of C and N ions.

The elements such as carbon, nitrogen and oxygen have been frequently used by the cyclotron users. Ion beams of carbon and oxygen are produced by using gases of CH4 and CO2. In order to enhance the high charge state of ion, either helium or oxygen is used as mixing gas .

When extraction voltage is higher, larger currents can be attained. For example, the current for C 5+ increased from 2.5μA at 3 kV to 11μA at 10 kV. This is probably due to a decrease of the transeverse emittance at high extraction voltage. An 18 O 6+ current are produced using 50 % enriched oxygen gas. If mono-isotopic oxygen were used the currents would be about twice as large.

A typical lithium spectrum tuned for 6 Li 2+ is shown in Fig. 4. Helium is used as support gas. The rf and filament power are both about 100 W. In this spectrum a beam intensity of other spectrum such as nitrogen and oxygen become smaller,when lithium vapor is injected into the plasma. It would be probably that lithium acts as a getter and quickly reduces the remaining levels of oxygen, nitrogen and carbon in the source.

Before long new beams such as Na will be developed.

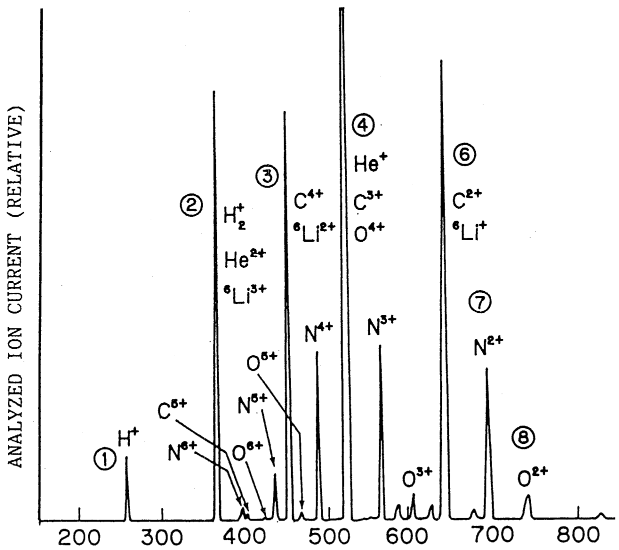

Fig. 4 A spectrum of 6 Li beam from ECR ion source tuned for 6 Li 2+.

References

[1] M. Oyaizu et al., Proc. 10th Int. Workshop on ECR Ion Sources (ORNL Report #CONF-9011136, Nov.,1990) pp. 25-34

[2] Y. Ohshiro et al., Proc. 7th Symp. on Accelerator Science and Technology, 1989, Osaka, Japan, pp. 65-67

[3] M. Sekiguchi et al., INS Annual Report 1989, p.128